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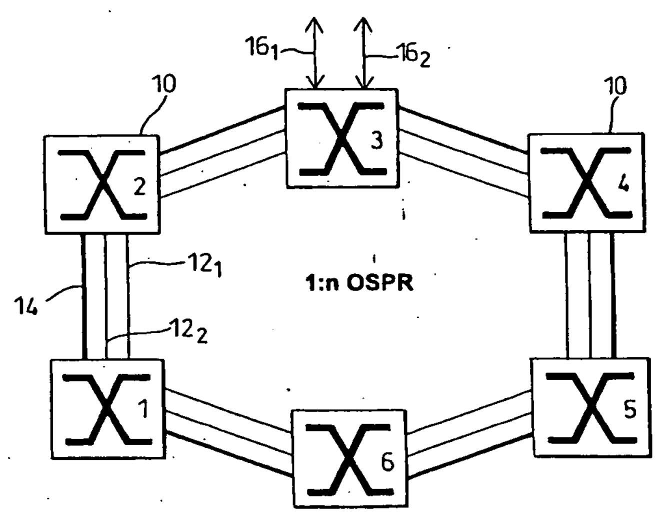

(57) Abstract: An optical network has adjacent pairs of nodes in a ring connected by a working optical fiber or fibers and by a protection optical fiber or fibers of lower bandwidth. Each node comprises an optical switching arrangement for switching signals from at least one external input to the node onto a protection fiber, each node further comprising a detector for detecting signal failure or degradation on the or each incoming working fiber. The optical switching is controlled in dependence on the detected signal failure or degradation. An optically switched protected ring configuration is thereby provided with shared protection allocation, for example 1:n protection. The sharing of protection bandwidth between greater bandwidth working fibers improves the fiber efficiency. This requires the signals on the working fibers to be allocated a level of service, so that premium channels are protected against cable failure because they have the lower protection bandwidth allocated to them.

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OPTICAL COMMUNICATIONS NETWORK AND NODE FOR FORMING SUCH A NETWORK

Field of the invention

This invention relates to an optical communications network which is defined by a number of interconnected nodes. The invention is particularly directed to a network in which protection paths are provided, which enable communication between pairs of nodes despite rupture of the main signal carrying fibre between those nodes.

Background of the invention

One possible way to provide a protection path between nodes is, for each adjacent pair of nodes of the network, to provide an additional protection cable between the pair of nodes which preferably follows a different path around the network to the main signal carrying fibre joining those nodes. This ensures that the protection cable is not susceptible to the same failure as the main cable. This type of dedicated protection scheme results in a large number of additional cables extending around the network, and these additional cables are normally unused. This approach is therefore bandwidth inefficient, although it is extremely simple to implement.

A known improvement to this approach is a ring configuration in which adjacent nodes are connected together by pairs of cables - a working cable and a protection cable. This enables the protection channels to be shared. This configuration has been considered for coupling nodes together which are each arranged to add or drop signals in standard SONET format to or from the network. The signals are provided from the service platform on two channels - a working channel and a protection channel. The nodes enable electrical switching of the entire signal carried by the working fibres onto the protection cables. This enables a span switch (in which for one section of the network between adjacent nodes, the protection fibre is employed instead of the main fibre) or a ring switch (in which signals for communication between adjacent nodes are redirected all around the network using the protection cables) to be implemented.

It is also known to couple nodes in a ring via two multiplexed communication paths providing for transmission in opposite directions around the ring. In normal operation, communications are

effected between the nodes in both directions via the two paths. This enables the shortest path between nodes to be used for communication in both directions. In the presence of a fault such as a fiber cut, this is detected in the two nodes immediately adjacent to the fault, and communications are maintained via both paths forming a folded loop, signals being coupled between the paths at these two nodes adjacent to the fault. Such systems are known as bidirectional line switched ring (BLSR) systems, and typically serve for communicating SONET signals in which case they are commonly referred to as SONET ring systems.

In BLSR systems (and other ring protection schemes), protection bandwidth is allocated by automatic switching in the event of a detected failure, so that the response to a signal failure is extremely fast, for example less than 50ms response time. However, there may be more bandwidth allocated to protection channels than is actually desired by users of the network (who pay for this extra bandwidth).

The operation of a BLSR system is described in greater detail in US5 159 595, which is incorporated herein as reference material.

Mesh based network architectures are also known, which minimise the amount of spare capacity required by allowing the spare capacity on one span to contribute to the protection of other spans. Intelligent switching and routing operations are required to implement the protection in the event of one or more failures, and such systems are extremely computationally intensive. Mesh based architectures also require more expensive hardware, and give slower response times to signal failures, but are efficient in their use of protection bandwidth.

In order to provide survivability of existing communication systems, it is possible to use digital cross connects (DCCs) at the nodes of the system for rerouting signals in the event of a link failure. DCCs are electronic switches, for example operating on DS3 signals. However, the use of DCCs involves considerable disadvantages of cost, equipment capacity, complexity, size, and power consumption, and slow protection in the event of a fault. It has also been proposed to use optical cross connects (OCCs) to provide for survivability of optical communication systems or networks, the OCCs serving to switch optical signals.

The invention aims to provide a network architecture in which protection bandwidth is allocated efficiently, and yet the response time to signal failures remains rapid.

Summary of the invention

According to the present invention, there is provided an optical communications network comprising at least three nodes linked in a ring configuration, adjacent pairs of nodes in the ring being connected by a working optical fiber or fibers and by a protection optical fiber or fibers of lower bandwidth than the working fiber or fibers, the working fiber or fibers carrying wavelength division multiplexed signals, wherein each node comprises an optical switching arrangement for switching signals from at least one external input to the node onto a protection fiber, each node further comprising a detector for detecting signal failure or degradation on the or each incoming working fiber, wherein the optical switching is controlled in dependence on the detected signal failure or degradation.

The invention provides an optically switched protected ring configuration with shared protection allocation, for example 1:n protection (i.e. 1 unit of protection bandwidth for n units of working bandwidth). The sharing of protection bandwidth between greater bandwidth working fibers improves the fiber efficiency. This requires the signals on the working fibers to be allocated a level of service, so that premium channels are protected against cable failure because they have the lower protection bandwidth allocated to them.

Preferably, there are at least two working fibers, and the protection fiber or fibers may be used during maintenance of all working fibers individually. Thus, 1:n protection is implemented as 1 protection fiber for n working fibers. The protection fiber can also carry extra traffic channels during normal operation, which channels are lost in the event of a protection switch.

The optical switching of signals onto the protection fibers reduces the amount of opto-electric conversion required in the network.

Essentially, the invention extends the BLSR protocol (GR1230) by allowing 1:n allocation of

protection bandwidth, for example as set out in Bellcore 253 which defines a point to point 1:n SONET system, with optical switching of signals onto the protection fibers.

The protection may be 1:n, and one of the n working fibers may then be allocated to premium channels, wherein signals for the said one working fiber are provided to a designated input to the node and are given preference to the protection bandwidth. Thus, the data input to the node which is to be protected is applied to a specified input, which is then associated with the one working fiber which, by default, has protection bandwidth allocated to it.

The network will normally comprise a plurality of rings, and ring spans which are common to adjacent rings may share a protection fiber.

Each node preferably comprises the optical switching arrangement and a wavelength division multiplexing unit for providing the signals for the working and protection fibers on allocated wavelengths.

Preferably, each node further comprises opto-electric conversion circuitry and header reading and updating circuitry to enable detected signal failures to be signalled to other nodes. However, this electro-optic conversion may only need to be carried out by the source node and the destination node.

According to a second aspect of the invention, in an optical communications network comprising at least three nodes linked in a ring configuration, adjacent pairs of nodes in the ring being connected by a working optical fiber or fibers and by a protection optical fiber or fibers of lower bandwidth than the working fiber or fibers, the working fiber or fibers carrying wavelength division multiplexed signals, a method of routing data to be protected between a source node and a destination node, there is provided a method comprising

at the source node, providing the data to a designated input of the node, the node providing the data on a working fiber;

monitoring signal failure or degradation on the incoming working fiber to the destination node;

in the event of signal failure or degradation, signalling the failure or degradation to the source node, and optically switching signals from the designated input at the source node onto an allocated protection fiber; and

at the destination node, optically switching signals from the allocated protection fiber to the output of the node.

This method enables 1:n protection to be provided, with automatic allocation of the protection bandwidth to a particular working fiber (or part of the bandwidth of the working fiber), which is associated with a designated input of a source node. In the event of signal failure, the source node, by default optically switches the input signal at the designated input onto the protection fiber. For nodes other than the source or destination nodes, protection fibers to and from the node are optically coupled together, and wherein there is no monitoring of signal failure for said nodes other than a destination node. In this way, there is no need for any electro-optic conversion in these intermediate nodes, since header information needs to be read and updated at the source and destination nodes. The intermediate nodes can therefore operate in a pass-through mode.

Preferably, there is a first number of working optical fibers and a second, lower, number of protection optical fibers.

The invention also provides an optical node for adding and/or dropping data to or from an optical network, the network having at least three nodes linked in a ring configuration, adjacent pairs of nodes in the ring being connected by a working optical fiber or fibers and by a protection optical fiber or fibers of lower bandwidth than the working fiber or fibers, the working fiber or fibers carrying wavelength division multiplexed signals, wherein the node comprises an optical switching arrangement for switching signals from a designated input to the node onto a selected protection fiber, and a detector for detecting signal failure or degradation on the or each incoming working fiber, wherein the optical switching is controlled in dependence on the detected signal failure or degradation.

Brief description of the drawings

The invention will now be described by way of example with reference to the accompanying

drawings, in which:

Figure 1 shows a network architecture according to the invention;

Figures 2a and 2b show two possible node architectures of the invention

Figure 3 is used to explain the operation of the network in the event of a single working fiber failure;

Figure 4 is used to explain the operation of the network in the event of failure of all fibers between a pair of nodes;

Figure 5 is used to explain the operation of the network in the event of node failure; and

Figure 6 shows how multiple ring architectures may form a mesh-like network.

Detailed description of the invention

Figure 1 shows a network architecture according to the invention. The network comprises a ring of nodes 10 (numbered 1 to 6), with adjacent pairs of nodes in the ring being connected by a first number of working optical fibers 12 and by a second, lower, number of protection optical fibers 14. In the example shown, there are two working fibers between the nodes and one protection fiber. The working fibers carry wavelength division multiplexed signals.

The nodes are provided for adding signals to the ring or removing signals from the ring, so that nodes may communicate with each other.

Each node comprises an optical switching arrangement for switching input signals from at least one designated input to the node onto the protection fiber. For example, node 3 is shown as having one port 16_1 associated with one of the working fibers 12_1 and one port 16_2 associated with the other working fiber 12_2. The data provided to port 16_1 may be intended to be protected by the shared protection bandwidth offered by the protection fibers 14 and constitutes high priority data, whereas the data provided to the port 16_2 may have lower priority. This means that the network operator can provide different levels of service according to customer's demands, and can therefore create a price structure for the use of the network which takes account of the level of protection required.

Each node has a detector for detecting signal failure on each incoming working fiber, so that protection switching can be controlled in the event of a detected failure. This protection switching is then carried out using an optical switching arrangement. In the event of detected failure of incoming signals, priority is given to the data on the working fiber 12_1, and to achieve this, the optical switching arrangement will normally switch rapidly to the appropriate configuration for routing data of the working fiber 12_1 onto the protection fiber 14, in the desired manner to provide the required ring or span switch.

Each fiber has an Optical Service Channel, and the OSC of the protection fiber can be used for protection signalling between nodes, whereas the OSC on the working fibers can be used for signal fail detection only. The manner by which the optical service channel can be used for signalling purposes will be well known to those skilled in the art. Alternatively, protection signalling can be carried out using a data wrapper around the signal.

A destination node will monitor the working fiber traffic in order to detect the interruption of service. This then triggers the node to send a message to the other nodes in the ring using the protection fibers.

The invention provides an architecture which protects the working fibers on a 1:n basis, and can operate using a protocol based on the 1:1 BLSR ring protocol and the 1:n APS (Automatic Protection Switching) linear protocol. Premium channels are routed to the working fiber designated as high priority, whereas best effort channels are routed to the other fibers. Extra traffic channels can also be routed to the protection fiber, which will be lost during maintenance (when the protection fibers are used to protect a selected working fiber when it is shut down for maintenance or repair) or during protection switching.

Figure 2a shows schematically the layout of the protection switching part of one of the nodes 10 of Figure 1 with a first design. A working fibers W and a protection fiber P connect to the node on the east and west sides of the node, and these are bi-directional fibers (or they may of course comprise fiber pairs). The input/output ports 16 to the node 10 connect to any source of optical data. Different ports 16 are allocated to traffic for eastbound and for westbound directions, and

different ports are provided for the two working fibers W1 and W2. These two working fibers may comprise separate fibers or they may represent data multiplexed together on a single working fiber W. For clarity, Figure 2a shows a single working fiber eastbound and westbound of the node. Each port 16_1, 16_2 has two terminals: one for eastbound and one for westbound traffic.

The multiplexer/demultiplexer 32 obtains the individual channels from the WDM signals on the working and protection fibers. In a preferred example, there may be three fibers (one protection and two working).

The traffic supplied to the ports 16 is protected traffic, and if unprotected traffic is provided by a user, this does not need to pass through the protection switching part of the node. An optical module 18 performs splitting and combining functions, and splits the client signal into working and protection components optically. The incoming working component is placed onto the appropriate WDM fiber (working fiber 1 eastbound or westbound, or working fiber 2 eastbound or westbound). The signal is first boosted by a wavelength translating unit (transponder) 20. This is a device which performs optical-electric-optical conversion, and enables amplification as well as channel allocation functions to be performed. When the signal is in the electrical domain, the frame overhead information can also be read. The protection component of an incoming client signal is also supplied to a wavelength translator 22 for signal boosting (to compensate for anticipated losses through the optical switch).

In the example of Figure 2a, protection signalling and failure detection is done by means of wrapper cards. For this purpose, the signal is also wrapped at the translators 22, as well as being translated to a wavelength on the ITU grid. The signals are then supplied to the optical switch 24, which takes the form of a photonic cross connect (PXC) 24. This comprises a matrix of optical switches, enabling the signals on any one port to be selectively coupled to any other port. The optical switches can comprise any desired form, for example being optomechanical devices in which prisms are moved, or being thermo-optic devices in which the refractive index of a polymer is changed by controlling its temperature, in each case to switch optical signals passing through the devices in accordance with electrical control signals.

As one preferred example, 2D micro electromechanical silicon mirrors can be flipped up or down, or 3D mirrors can be flipped up or down and side to side. At present, PXCs with 1024 x 1024 ports can be fabricated using mirror techniques.

In a default setting, the PXC does not route the protection component to any of its outputs. This represents the required connectivity when there is no protection activity. However, the PXC also enables the protection component received from the wavelength translators / wrappers 22 to be switched onto the eastbound or westbound protection fiber. This enables ring and span switches to be implemented, as will be described in the following. A span switch involves routing the protection component to the protection fiber in the short path direction to the destination node, and a ring switch involves routing the protection component to the protection fiber in the long path direction to the destination node.

Protection traffic received by the PXC can be routed to the modules 18 The module 18 can then selectively route either the working fiber signal or the signal from the PXC to the client receiver. To enable the protection signalling to be used, the protection wavelengths are terminated with regenerators 26 which read the signal wrappers and thereby provide data to a control unit 27. Similar devices enable the wrapping operation to be carried out with suitable signalling information provided in the data wrapper.

In order to determine the required protection switching, the nodes have a detector for detecting signal failure on each incoming working fiber. This comprises the wavelength translator 20 allocated to that incoming fiber. Thus, the bank of wavelength translators can select the channel onto which data is provided when sent out from a node, and also be used for measurement of signals coming into the node. This measurement detects signal failure on channels of the incoming working fiber. There is a signalling interface between the PXC controller 27 and the transponders 20 used for failure detection, which may be an ethernet interface. The transponders associated with the working fibers provide the signal failure or degradation information, but are not used for any signalling operations.

The multiplexer/demultiplexer 32 will divide the WDM signal into the individual channels, so that failure detection is on a channel by channel basis, with failure detection of each channel by an associated transponder 20.

A destination node will monitor incoming signals from the working fiber being used, in order to detect the interruption of service. This then triggers the node to send a message to the other nodes in the ring using the protection fibers, and this is carried out by updating a signal overhead contained in the data wrapper. This data wrapper overhead is carried by optical K-bytes.

It is also possible to monitor signal degradation (instead of failure) and to perform protection switching if it is judged that an unacceptable error ratio is likely to occur. Signal degradation can be monitored entirely optically, and may involve measurement of the so-called "Optical Q Value".

In the configuration shown in Figure 2a, the PXC is on the client side (tributary side) of the transponders 20 used for failure detection. Alternatively, the transponders 20 may be provided at the ports 16, so that the PXC is on the line side. A second design of node architecture, which implements this arrangement, is shown Figure 2b.

Where the same components are used as in the example of Figure 2a, the same reference numerals are used. The individual channels are supplied directly to the modules 18 from the multiplexers/demultiplexers 32 In this case, there is no opto-electric conversion before the PXC 24, so that the switching fabric is entirely optical. In this case, it is preferred not to require reading or updating of data wrappers, and instead the Optical Service Channel 38 is used for protection signalling.

Each incoming working fiber is branched to provide a signal to the module 18 and to a monitor 34. The module 18 again enable signals to be dropped to the client receiver either from the working fibers or from the protection fiber (via the PXC 24). The monitor 34 monitors signal degrade, for example by measuring the optical Q of the incoming signal. The transponders 20 may also be used for failure detection of the working fiber signals, and will then communicate

with the monitors 34. However, it is also possible to use all-optical signal monitoring.

The monitoring information is supplied to a control unit 36 which in turn controls the protection signalling operation. The protection signalling involves updating the OSC 38 carried by the protection fiber. The OSC is also monitored by the control unit 36 to enable signalling from other nodes to be interpreted. As mentioned above, the OSC is carried by the optical K-bytes

In the event of a detected signal failure at the incoming working fiber channels, the controller 36 is alerted to the failure. This detected signal failure is by the monitors 34. The controller then applies K-byte signalling on the OSC of the protection fiber using transponders 28. This provides information to the other nodes in the ring.

In either design, the transponders 20 (whether on the line side or the client side) enable the signals to be assigned to available channels when signals are switched from one fiber to another or between the client equipment and the fiber channels.

When a node is along the path of a ring or span connection, the PXC can be switched for unidirectional or bidirectional pass through of the protection traffic. The nodes between the source and destination nodes also act in pass-through mode for the working traffic, so that there is no coupling of the working traffic onto the protection fibers at those nodes. This means the working fibers are essentially coupled together. This may be achieved by hard wiring those connections although regeneration at the node may nevertheless be required. Alternatively, the intermediate node connections of the working fibers may be made through an electrical cross connect.

If protection switching on a fiber level is required, a small cross connect can be used, for example a 12 x 12 PXC, with the twelve ports shown in Figures 2a and 2b. In such a case, the individual channels are remultiplexed together at the inputs of the PXC so that the PXC performs switching of an entire fiber signal. If, alternatively, wavelength selective optical switching is required, so that protection can be allocated on a per wavelength basis, then a much larger cross connect is required with inputs and outputs for each channel. The granularity of the PXC switching may

also be per band of wavelengths, in which case the PXC inputs will be provided with multiplexers for combining the channels within the bands.

The detection of failure for a particular channel only needs to take place at the destination node, and does not need to take place in any intermediate nodes between the source node and the destination node. Instead, any protection switching can take place only in the source and destination nodes, whereas the PXCs of the other nodes act in pass through mode for the protection traffic. The required signalling and detection to enable protection switching is therefore reduced.

Figure 3 shows a failure 40 in one of the working fibers (i.e. in a receiver or transmitter). If the intended data path was from node 2 to node 6, failure would be detected at node 6, which would be signalled to node 1 using the protection fiber. This signalling results in a span switch, so that the protection fiber is used between nodes 2 and 1, and between nodes 1 and 6, and no failure detection is required by node 1 which is not a destination node. Node 1 for this optical channel is a glassthough or regeneration site. When K-byte signalling is used for the protection signalling, 4 dedicated bytes may be provided at 128 kbits/s (whereas BLSR uses 2 such bytes). Where protection signalling is by means of a data wrapper, much higher data rates of protection signalling are available.

Depending on the levels of service being provided, a failure in working fiber W2 can only result in protection switching if there is no other failure requiring protection bandwidth. This will be the case when the user has not paid for a higher level of service. If the failure affects fiber W1, this will result in a protection switching of the optical cross connect in preference over W2. If a failure affects both working fibers, then the fiber W1 will have priority, so that a priority scheme is implemented.

All nodes in the ring are informed by the signalling that a span switch is in operation.

Figure 4 shows a complete cable cut 42 between nodes 1 and 2. Ring protection is triggered by the failure (in the same way as for BLSR), but the protection signalling also indicates which of

the working fibers of the span between nodes 1 and 2 carries the higher priority data, which will be allocated the protection bandwidth. This may automatically be assumed to be working fiber W1, which enables the protocol to be simplified. In such as case, the highest priority data to be provided to a source node will always be applied to the port associated with the working fiber W1.

Figure 5 shows a node failure 44 in node 1. In this case, nodes 2 and 6 will ring switch away from node 1.

The required signalling to implement the invention can be implemented as a simple modification to the existing BLSR protocol, which will be known to those skilled in the art.

When the capacity of a network is increased, rings may be stacked on top of each other. The invention may be used to enable the protection fibers in one ring to be shared with other layers of ring architectures.

Figure 6 shows how multiple ring architectures may form a mesh-like network. Where spans are in two rings, the protection fibers may be shared between those rings.

The specific example described above has 1:2 protection. The invention can equally be applied to give n:m protection, although more complicated signalling and priority schemes will be required.

We Claim

1. An optical communications network comprising at least three nodes linked in a ring configuration, adjacent pairs of nodes in the ring being connected by a working optical fiber or fibers and by a protection optical fiber or fibers of lower bandwidth than the working fiber or fibers, the working fiber or fibers carrying wavelength division multiplexed signals, wherein each node comprises an optical switching arrangement for switching signals from at least one external input to the node onto a protection fiber, each node further comprising a detector for detecting signal failure or degradation on the or each incoming working fiber, wherein the optical switching is controlled in dependence on the detected signal failure or degradation.

2. A network as claimed in claim 1, wherein the adjacent pairs of nodes are connected by a first number of working optical fibers and by a second, lower, number of protection optical fibers.

3. A network as claimed in claim 2, wherein the first number is 2 or more, and the second number is 1.

4. A network as claimed in claim 2 or claim 3, wherein one of the working fibers is allocated to premium channels, wherein signals for the said one working fiber, are provided to a designated input to the node and are given preference to the protection bandwidth.

5. A network as claimed in any of the above claims, comprising a plurality of rings and wherein ring spans which are common to adjacent rings share a protection fiber.

6. A network as claimed in any of the above claims, wherein each node comprises the optical switching arrangement and a wavelength division multiplexing unit for providing the signals for the working and protection fibers on allocated wavelengths.

7. A network as claimed in any of the above claims, wherein each node further comprises

opto-electric conversion circuitry and header reading and updating circuitry to enable detected signal failures to be signalled to other nodes.

8. In an optical communications network comprising at least three nodes linked in a ring configuration, adjacent pairs of nodes in the ring being connected by a working optical fiber or fibers and by a protection optical fiber or fibers of lower bandwidth than the working fiber or fibers, the working fiber or fibers carrying wavelength division multiplexed signals, a method of routing data to be protected between a source node and a destination node, there is provided a method comprising

at the source node, providing the data to a designated input of the node, the node providing the data on a working fiber;

monitoring signal failure or degradation on the incoming working fiber to the destination node;

in the event of signal failure or degradation, signalling the failure or degradation to the source node, and optically switching signals from the designated input at the source node onto an allocated protection fiber; and

at the destination node, optically switching signals from the allocated protection fiber to the output of the node.

9. A method according to claim 8, in which, for nodes other than the source or destination nodes, protection fibers to and from the node are optically coupled together, and wherein there is no monitoring of signal failure for said nodes other than a destination node.

10. A method as claimed in claim 8 or claim 9, wherein adjacent pairs of nodes in the ring are connected by a first number of working optical fibers and a second, lower, number of protection optical fibers.

11. An optical node for adding and/or dropping data to or from an optical network, the network having at least three nodes linked in a ring configuration, adjacent pairs of nodes in the ring being connected by a working optical fiber or fibers and by a protection optical fiber or fibers of lower bandwidth than the working fiber or fibers, the working fiber or fibers carrying

wavelength division multiplexed signals, wherein the node comprises an optical switching arrangement for switching signals from a designated input to the node onto a selected protection fiber, and a detector for detecting signal failure or degradation on the or each incoming working fiber, wherein the optical switching is controlled in dependence on the detected signal failure or degradation.

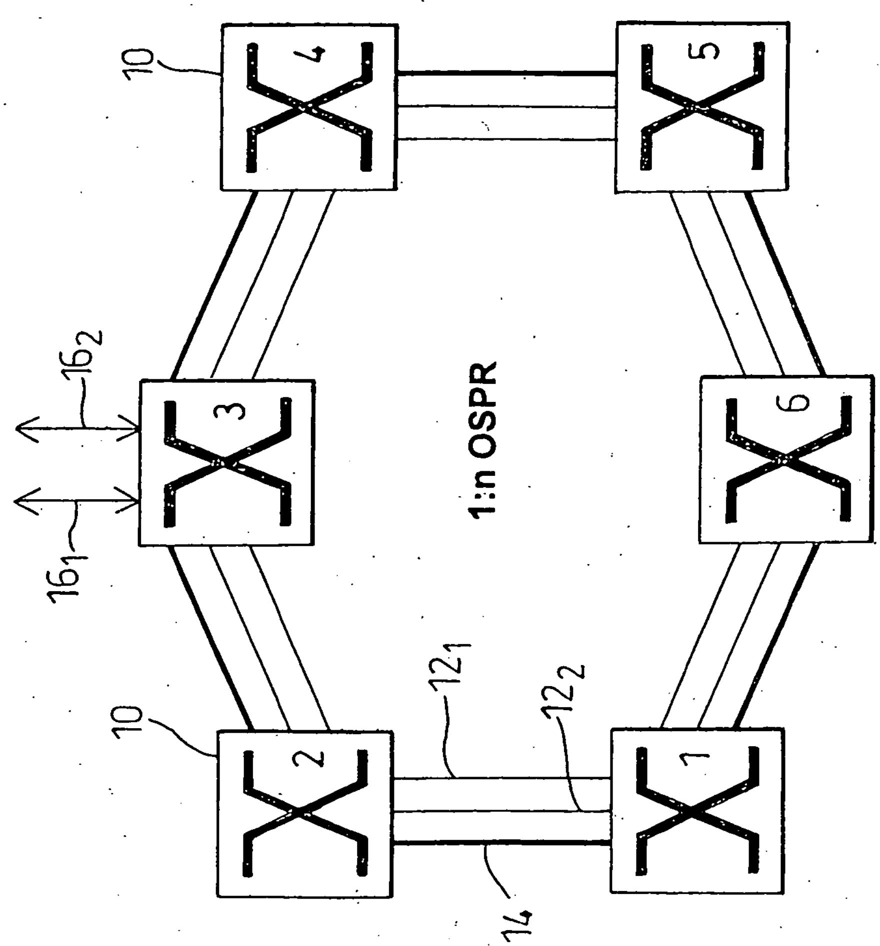
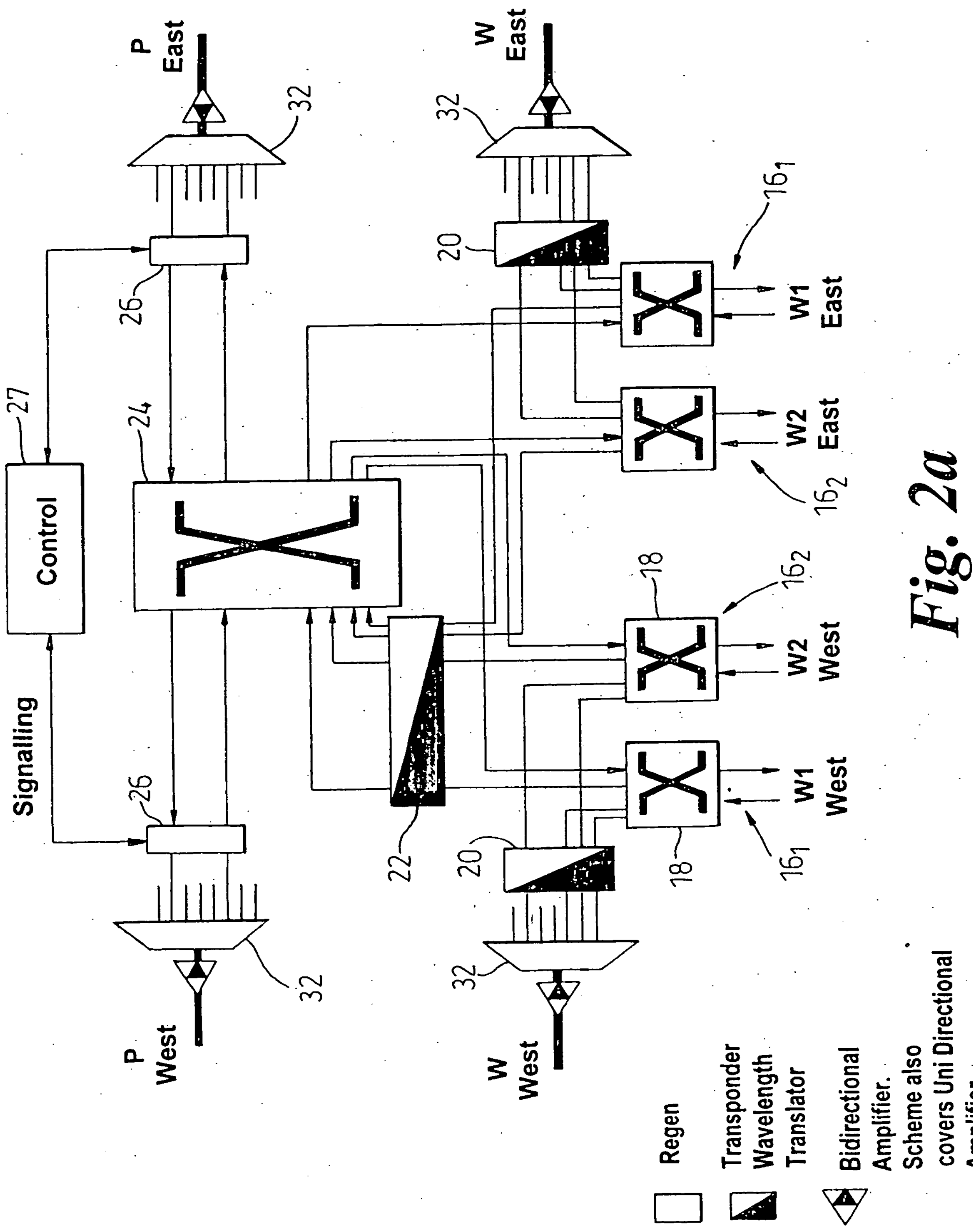


Fig. 1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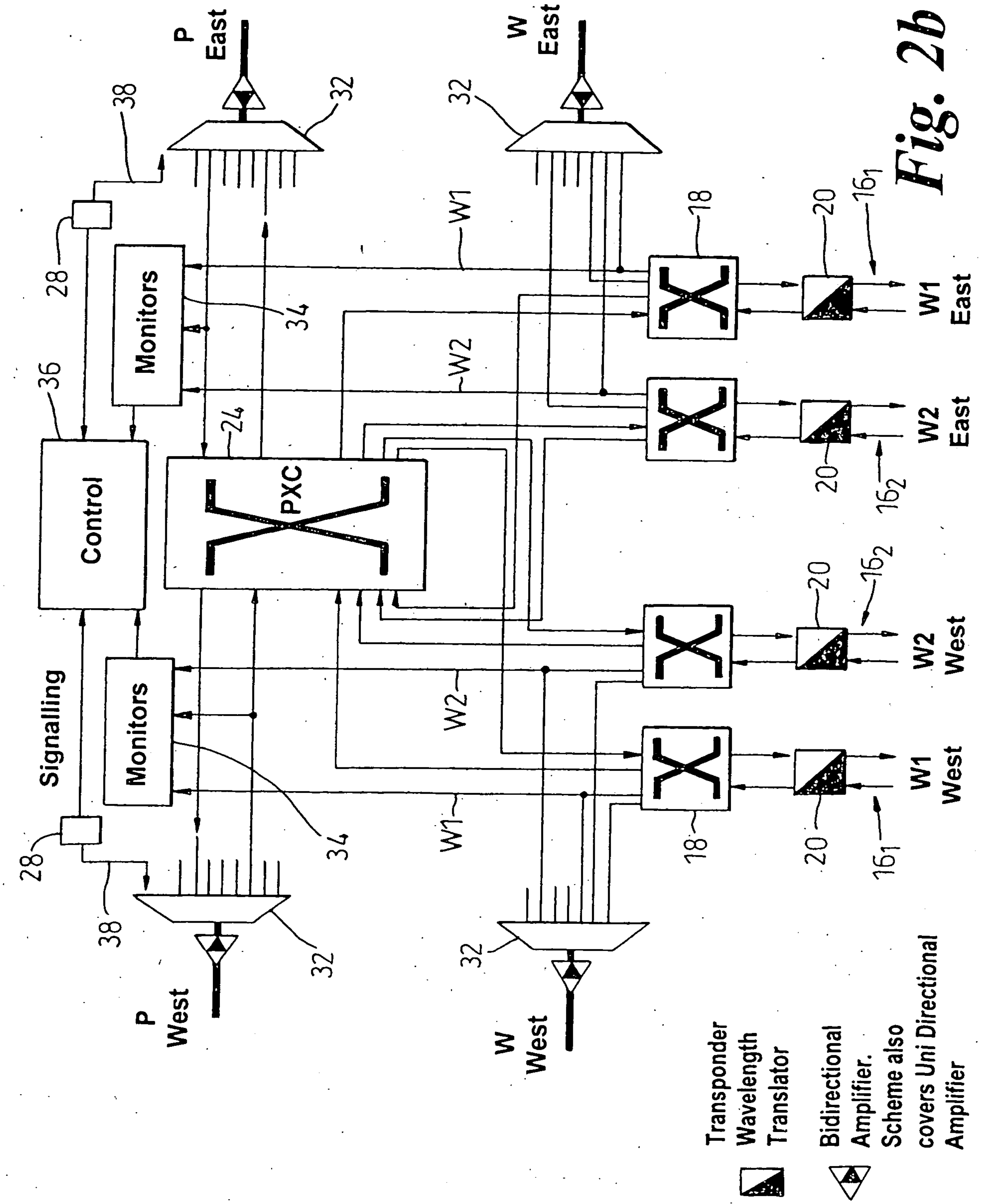
W East
P West
W West
32
26
27
Control
Signalling
24
22
20
18
16₁
16₂
W1 East
W2 East
W2 West
W1 West
Regen
Transponder Wavelength Translator
Bidirectional Amplifier. Scheme also covers Uni Directional Amplifier

Fig. 2a


P East
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Control
PXC
Monitors
Signalling
W1 East
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W2 West
W1 West
P West
W West
Transponder Wavelength Translator
Bidirectional Amplifier. Scheme also covers Uni Directional Amplifier

Fig. 2b

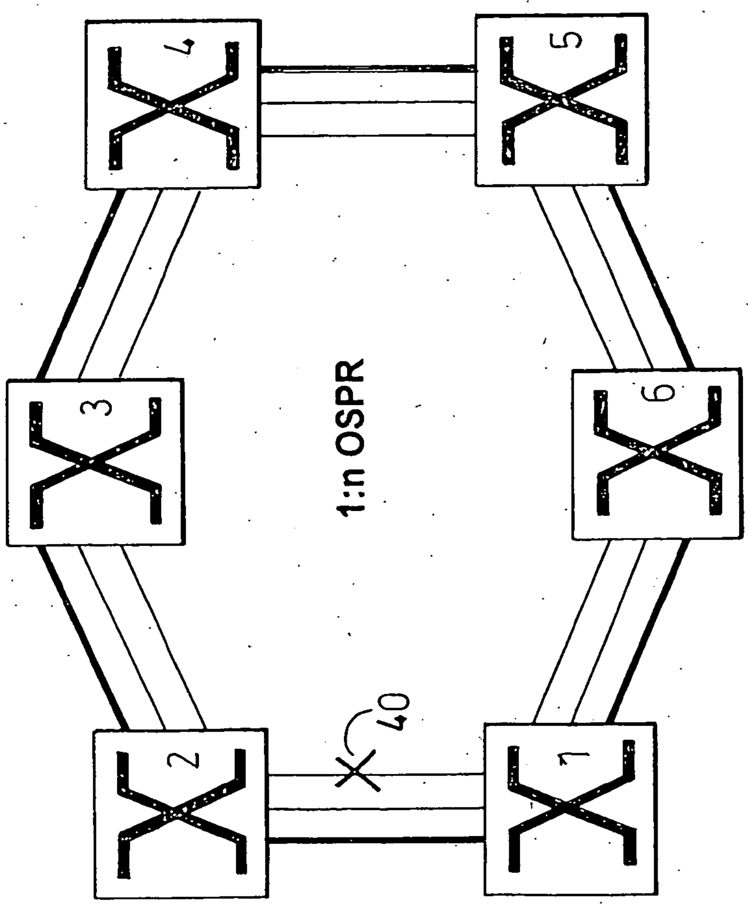

Fig. 3

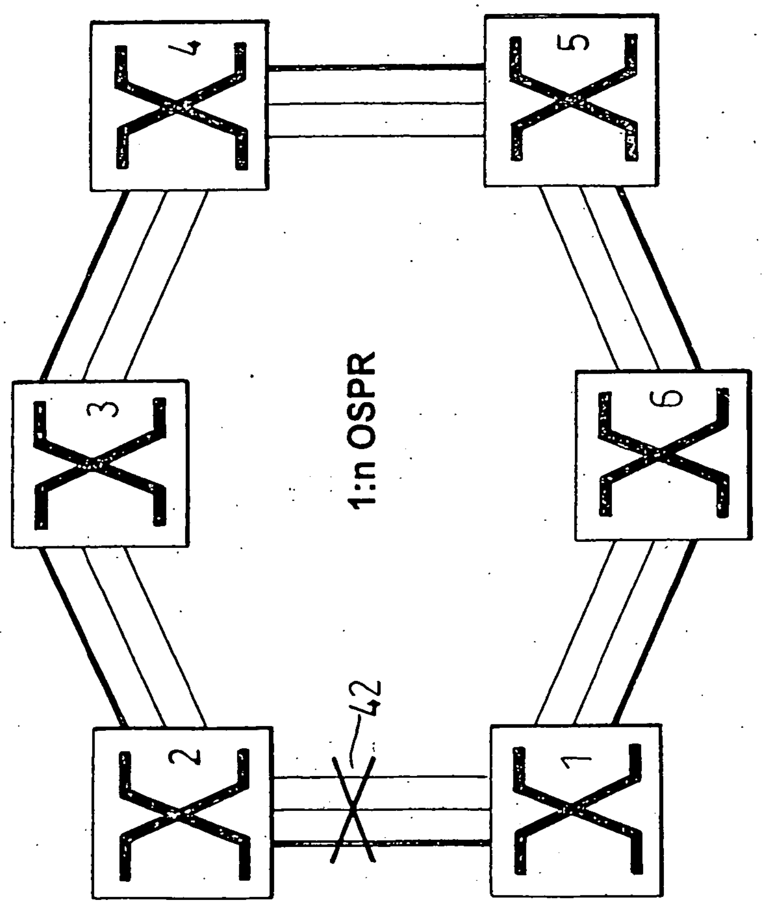

Fig. 4

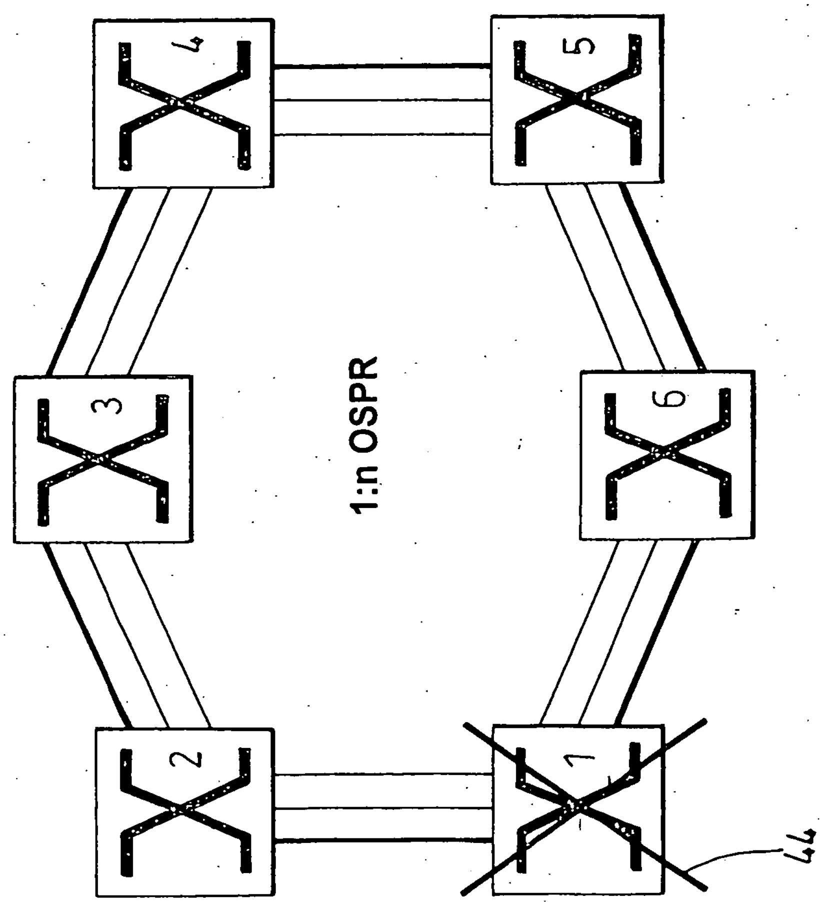

Fig. 5

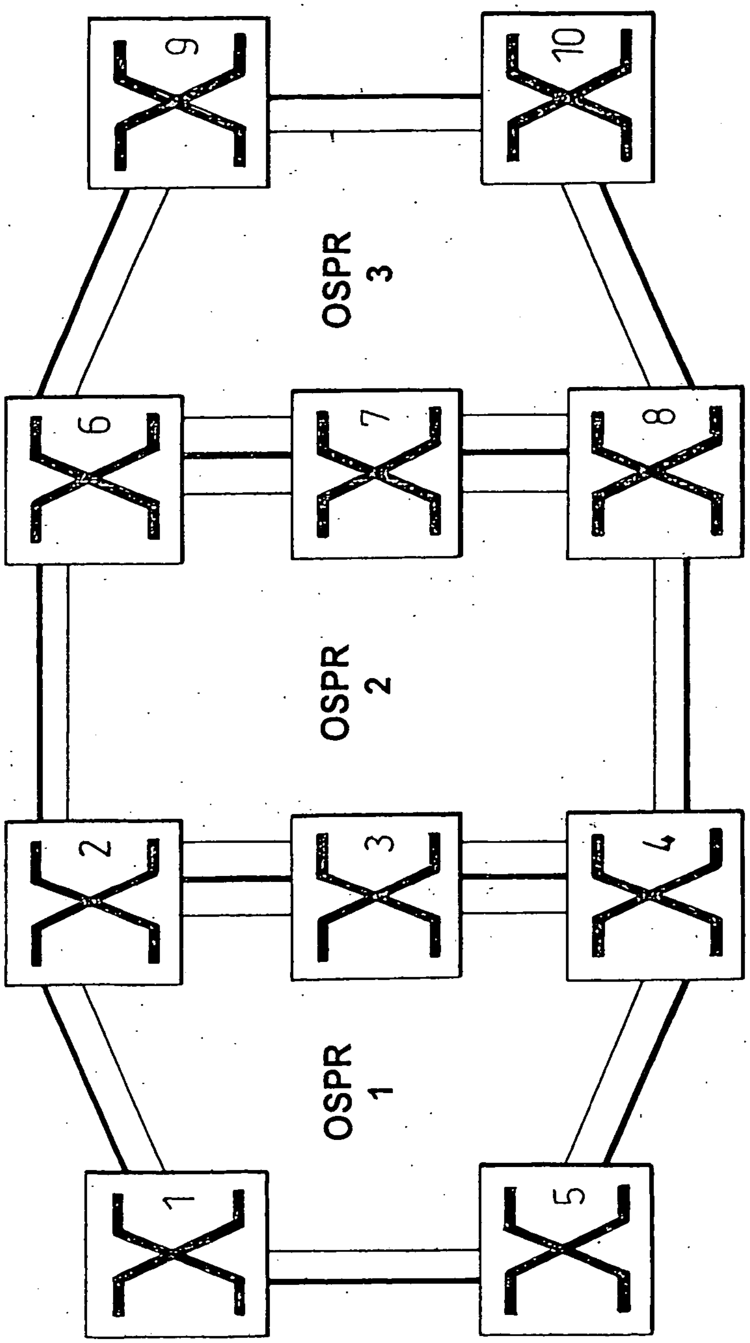

Fig. 6